Quantifying the carbon in harvested wood products from logs exported from New Zealand

Bruce Manley and David Evison

Abstract

In 2015, New Zealand exported 15.4 million m^3 of logs, some 53% of the national harvest, with 96% going to China, South Korea and India. Models have been developed to quantify the harvested wood products (HWP) manufactured in each country from these logs and the lifecycle of the HWP produced. The model allows the decay curve of the HWP carbon stock to be estimated. Carbon stocks in the products manufactured in China from New Zealand logs are halved in just under two years. Some 46% of the HWP is lumber and plywood used for temporary construction, while 13% is lumber and plywood used for packaging, which is also short-lived.

In South Korea, the carbon stocks are halved in just over 12 years. Although the 42% of material used for temporary construction has a short-life in that intermediate use, most is recycled into longer-lived particleboard. In addition, 30% of log volume (mainly sawmill slabwood and plymill residues) is used for the production of medium-density fibreboard (MDF), another long-lived panel product.

In India, the overall carbon stocks are halved in less than one year. Some 26% of the radiata pine log volume is directly used for fuel, including slabwood (14%) and most sawdust (12%), while construction lumber (27%) is also used for fuel after use for concrete formwork. Packaging material (31%) is also short-lived, particularly domestic packaging.

In combination, the aggregate decay curve for the three countries has carbon stocks halved in just over two years. These findings have implications for New Zealand's carbon accounting under the Kyoto Protocol and carbon reporting under the United Nations Framework Convention on Climate Change (UNFCCC). If the deferred liability for emissions from HWP is devolved to forest growers participating in the New Zealand Emissions Trading Scheme (NZ ETS), the decay rate adopted for HWP will have a major impact on the carbon stock profile over time for a tree crop, and hence forest profitability and risk and, consequently, the financial viability of afforestation.

Introduction

In the context of international climate change agreements, harvested wood products (HWP) 'are wood-based materials harvested from forests, which are used for the production of commodities such as furniture, plywood, and paper and paper-like products, or for energy' (UNFCCC, 2003, p5). HWP consists of all wood material, including bark, that leaves harvest sites (IPCC, 2006, p12.5).

New Zealand undertakes carbon reporting under the UNFCCC (United Nations Framework Convention on Climate Change) and carbon accounting under the Kyoto Protocol (Brandon & Searles, 2017). Different reporting requirements apply in each case. Although New Zealand did not sign up to the second commitment period (CP2), this country continues to apply the Kyoto Protocol framework of rules in tracking progress towards its 2020 target set under the UNFCCC.

For carbon reporting under the UNFCCC, New Zealand has adopted the production approach which:

> *… estimates changes in carbon stocks in the forest pool (and other wood producing lands) of the reporting country and the wood products pool containing products made from wood harvested in the reporting country. The wood products pool includes products made from domestic harvest that are exported and stored in uses in other countries (IPCC, 2006, p12.5).*

Consequently, New Zealand needs to report on the logs (and other HWP) exported from this country and the HWP produced from exported raw materials offshore. The default treatment is to assume that export logs are converted into products and consumed at the same rate as domestic production. New Zealand has modelled lifespans using the default first-order decay approach, with half-lives of 30 years for solid wood and two years for paper and paperboard.

Instant oxidation of HWP was assumed for Commitment Period 1 (CP1) of the Kyoto Protocol on the basis that, at a first approximation, the global pool was neither increasing nor decreasing. For CP2, IPCC (2014) still allows this as a Tier 1 approach where transparent and verifiable data on HWP are not available. However, when transparent and verifiable data are available, changes in the HWP pool are to be accounted for using a first-order decay function. Tier 3 applies when country-specific half-lives and/or methodologies are available. Otherwise Tier 2 applies. When Tier 2 is applied, default half-lives of 35 years, 25 years and two years are to be used for sawn wood, wood panels and paper, respectively. For the purposes of Kyoto accounting, good practice guidance (IPCC, 2014) is that the HWP pool should be limited to these three semi-finished categories. Carbon in other products (e.g. fuelwood, charcoal, posts and poles, animal bedding) should not be included in accounting and instead assumed to be instantly emitted.

New Zealand has developed a Tier 3 method to report HWP, based on the default Tier 2 methodology as described in the guidance (IPCC, 2014), with country-specific activity data and parameters where available. Under the Kyoto Protocol, separate accounting is required for different activities:

- HWP from post-1989 forests harvested from 1990
- HWP from pre-1990 forests harvested from 2013
- HWP from deforestation – instantly emitted.

HWP are accounted for by the country in which they were 'removed from forests'. Given that New Zealand has adopted a Tier 3 approach, in the case of exported HWP it is required to use country-specific half-lives and HWP usage for the importing country. This component is important given that most of the harvest volume is exported in log form (Figure 1). Since 2012, over 50% of the New Zealand harvest has been exported as logs. In 2015, 53% was exported and 57% in 2016. IPCC (2014) requires that for HWP to be included in Kyoto Protocol accounting, transparent and verifiable activity data is required. Although some information is available (e.g. MPI, 2014) on the conversion of export logs to products and their expected half-lives, it is limited. Exported raw materials have therefore been excluded from New Zealand's Kyoto Protocol HWP pool estimates and instead treated as an instantaneous emission.

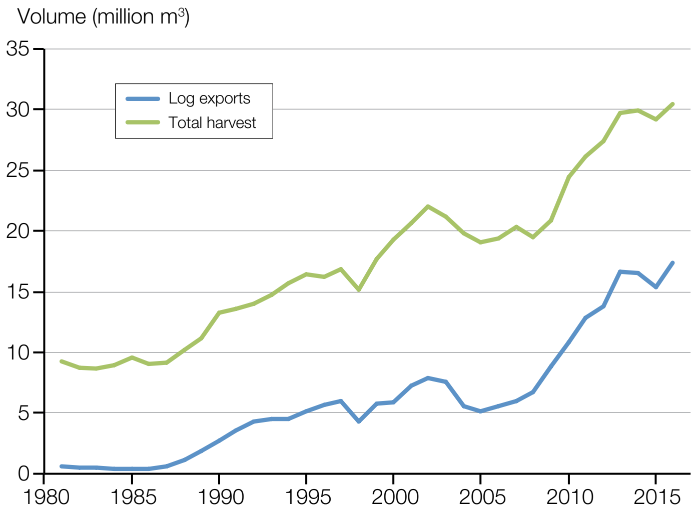

Figure 1: Volume harvested from NZ plantations and volume exported as logs. Source: MPI

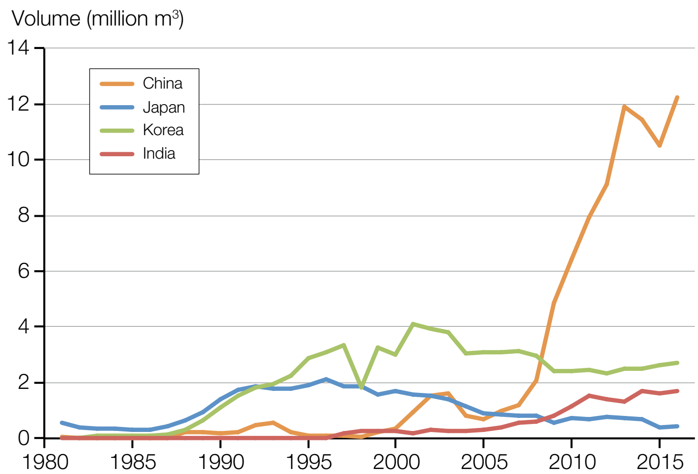

Figure 2: Volume of logs exported from NZ to major destinations. Source: MPI

In 2014, the Ministry for Primary Industries (MPI) commissioned a project to quantify the material flow of New Zealand logs for each of the major overseas markets. This was primarily to meet Kyoto Protocol CP2 accounting requirements, but also to assist in understanding New Zealand's export markets. It included tracking the volume and type of wood products produced from New Zealand grown roundwood together with the lifecycles of these HWP. The objective was to develop a robust methodology and models that support New Zealand to meet Kyoto Protocol requirements, and support reporting under the UNFCCC. The focus was on New Zealand's three major export log markets, which currently account for 96% of the market (Figure 2):

- China – 68% of 2015 log exports
- South Korea – 17%
- India – 11%.

Details of the models developed are given in Manley and Evison (2016). This paper provides a summary of these models, goes on to show the general implications for New Zealand, and in it we:

- Quantify the material flow and end use of New Zealand logs exported to China, South Korea and India
- Estimate the carbon decay curve for HWP manufactured in each country from New Zealand logs
- Estimate the carbon stocks, total and change in the HWP pool of logs exported to each country separately, and indicate the uncertainty associated with the estimates of carbon stock change
- Discuss implications for New Zealand for UNFCCC reporting and Kyoto Protocol accounting, as well as possible flow-on effects for the New Zealand Emissions Trading Scheme (NZ ETS).

Method

New Zealand log exporters were visited in late 2014/early 2015 and information was obtained about the grades that they exported. Those surveyed were also asked to estimate the products produced from the exported logs and their likely end use.

In 2015, visits were made to China, South Korea and India. In the case of China we visited each of the three main regions that import New Zealand logs:

- North – includes Shandong Province and the region around Beijing

- East – includes Shanghai and the Yangtze Delta
- South – includes Fujian Province and the Pearl River Delta.

We visited wood processing plants, wood product manufacturers, construction sites, ports, log yards, log traders, industry associations, researchers and government officials. These visits provided an overview of the material flow and end uses of the products produced from New Zealand export logs. From the information obtained we developed models for each country. The key modelling steps were:

1. Develop a material flow model for logs exported from New Zealand to each of China, South Korea and India.
2. Use this model and the half-lives in Table 1 to estimate the overall decay curve for HWP from logs exported to each country separately and in total.
3. Use the material flow model and log export statistics to estimate the HWP carbon pool and annual change for 1981 to 2016 from log exports to each country.

IPCC (2006) provides the first-order decay function used for each end product:

$$C(i+1) = e^{-k} * C(i) + [(1 - e^{-k})/k] * Inflow(i)$$

Where C(i) and C(i+1) are the carbon stock at time i and one year later

Inflow(i) is the additional carbon added during the year

k is the decay rate (=ln(2)/half-life).

Initial analysis considered the decay in the HWP carbon stock associated with 2015 log exports. Subsequently, the historical time series of log exports was considered. Volumes were converted to tonnes of CO_2 equivalent using a basic wood density value of 0.42 t/m^3, a wood carbon content value of 0.51 and a CO_2/C ratio of 44/12. Volumes exclude bark as much of the bark is removed in the harvesting process, particularly when log-making is mechanised. Higher-value pruned logs are often debarked before export. Any remaining bark is assumed, in the model, to oxidise immediately.

The uncertainty analysis was carried out by assigning a probability distribution function to key model inputs, which were primarily the inputs evaluated in sensitivity analyses by Manley and Evison (2016), and running 1,000 iterations. The 2.5 and 97.5 percentile values represent the 95% confidence interval.

Results

Material flow – China

In 2015, New Zealand exported 10.5 million m^3 of logs to China, 9.9 million m^3 of radiata pine, 0.5 million m^3 of Douglas fir and 0.1 million m^3 of minor species, including Corsican pine, poplar and Eucalypts. The most important use of New Zealand logs exported to China is for the production of temporary construction material (46%), followed by packaging (13%) and appearance products (10%) (Figure 3). The balance of outputs is sawmill (24%) and plymill (7%) residue. These residues are used to produce a range of products – longer-lived MDF and particleboard and shorter-lived pulp and fuel.

Construction lumber and plywood are used repeatedly on the construction site until no longer fit for purpose. Construction lumber is used two to seven times over a three-month period, while construction plywood is used four to eight times over a two to three-month period. A substantial proportion of the construction lumber and plywood is recycled into panel products of generally low quality, with the waste (i.e. very small pieces, delaminated plywood) burnt.

Much of the packaging lumber comes from re-sawing edge boards and is of a small dimension. Appearance lumber from primary conversion is often processed into re-manufactured products, such as edge-glued panels, finger-jointed mouldings, laminated posts and furniture components.

Sawmill slabwood is typically purchased by consolidators who chip the material at a central chipping plant. The consistent pattern we observed was that most chips were being transported (often over long distances exceeding 1,000 km) by road, rail or river to pulpmills in Hunan and Fujian Provinces. Sawdust is mainly burnt either directly as fuel or as pellets, incense or charcoal.

Table 1: Half-life* used for each product

End use	Half-life	Source
Appearance lumber	35	IPCC Default
Construction lumber	0.5	Information obtained
Packaging lumber	3	Estimate (Nabuurs, 1996)
Appearance plywood	25	IPCC Default
Construction plywood	0.5	Information obtained
Packaging plywood	3	Estimate (Nabuurs, 1996)
MDF	25	IPCC Default
Particleboard	25	IPCC default
Veneer core	2	Estimate
Pulp	2	IPCC Default
Pellets	0	Instant emission
Fuelwood	0	Instant emission
Recycled panels (China)	2	Estimate
Sawdust – agriculture (South Korea)	0	Instant emission
Blockboard (India)	7	Estimate
Packaging – domestic (India)	0.5	Estimate

* Half-life refers to the time taken for half of the carbon contained in wood products to be emitted. In contrast, average lifetime is the time, on average, during which a specific product is in use. In the case of an exponential decay function the half-life equals 0.693 of the average lifetime

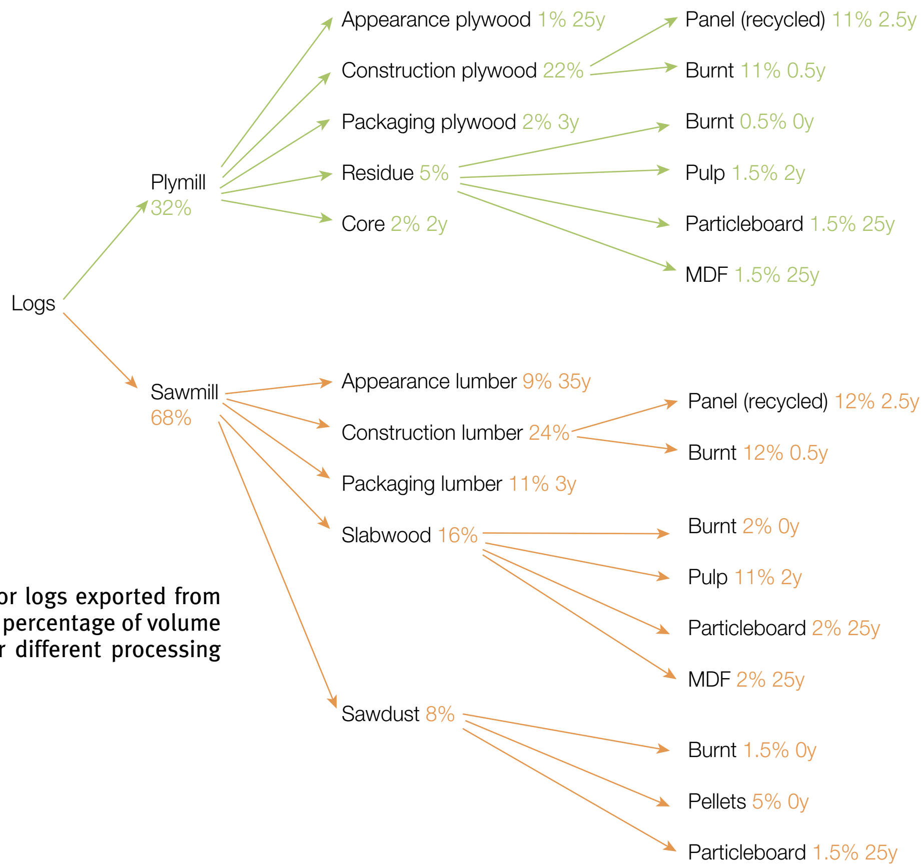

Figure 3: Outline of material flow for logs exported from NZ to China in 2015. Numbers show percentage of volume and pathway half-life (in years) for different processing and end-use pathways

Plymill residue (veneer ribbon from roundup, plywood trimmings) is used for particleboard, MDF, pulp and fuel. Veneer cores are used as mop handles or photo frames.

Overall the conversion from logs to plywood is 80%, while the conversion to sawn products is 64%. These conversion factors are not just for primary processing, rather they are the conversion from logs to final product.

Material flow – South Korea

In 2015, South Korea imported 2.6 million m^3 of logs from New Zealand, mainly radiata pine with a small volume of Douglas fir (about 25,000 m^3). As for China, the most important use of New Zealand logs exported to South Korea is for the production of temporary construction material (42%), with packaging lumber (14%) also important (Figure 4). However, a big driver of demand for radiata pine is from MDF companies. Although only 2% of logs are directly used for MDF, virtually all sawmill slabwood (20%) and plymill residue (8%) are chipped and used for MDF production. Sawmills are frequently operated by MDF companies to provide access to sawmill residues. Independent sawmills have agreements to supply residue to local MDF companies.

Although some sawdust is used for boiler fuel, most is used in agriculture for fertiliser (i.e. mulching) or animal beds, particularly for pig farming. These products are not considered HWP for the purposes of Kyoto Protocol accounting and are assumed to be instantly oxidised.

Construction timber and plywood is used about three times on the construction site until it is no longer fit for purpose. Most of it is then chipped and used for particleboard, although some is used as fuel and burnt.

Packaging lumber is used for pallets for domestic and export markets, cable drums and packaging around export products (e.g. for packing car parts sent abroad for assembly).

Material flow – India

In 2015, New Zealand exported 1.6 million m^3 of logs to India, all radiata pine and all for sawing. Radiata pine is not peeled in India. The most important use of sawn timber is for packaging (31%) and construction lumber (27%). Small pieces of slabwood are re-sawn for blockboard cores (13%), while slabwood (14%) and most sawdust (12%) are used for fuel.

The percentage of lumber production used for construction, rather than packaging, varies for individual mills between 0% and 100%. The average split of the 13 mills visited was 47% construction and 53% packaging. This split excludes blockboard, which is considered to be a by-product or arising at most mills.

Construction lumber is almost exclusively used as battens to strengthen and support plywood for concrete formwork. Typically 90 x 62 mm battens are used to support formwork for floors, with 62 x 45 mm battens used to support formwork for walls. Construction timber is reused about four times and then used for fuel, often by workers from the construction site.

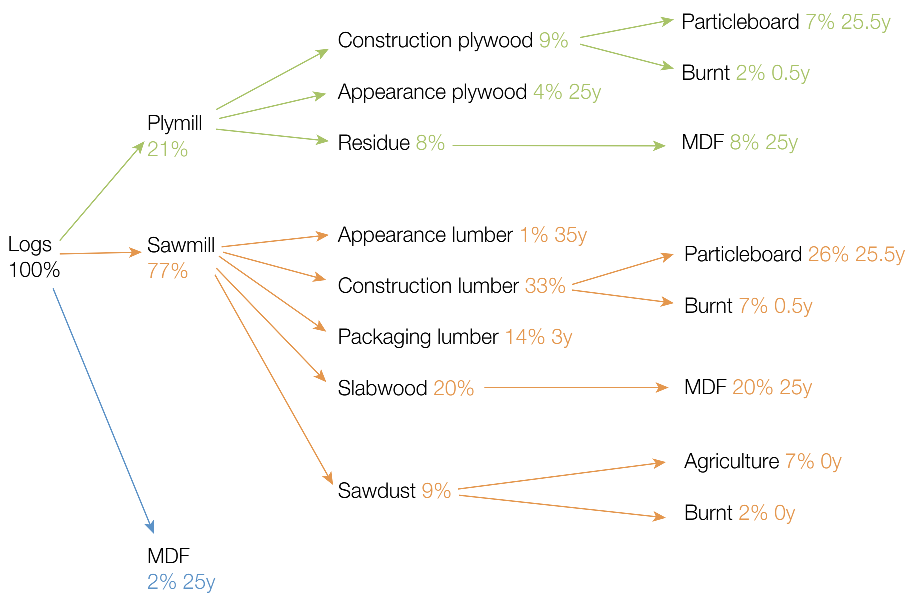

Figure 4: Outline of material flow for logs exported from NZ to South Korea in 2015. Numbers show percentage of volume and pathway half-life (in years) for different processing and end-use pathways

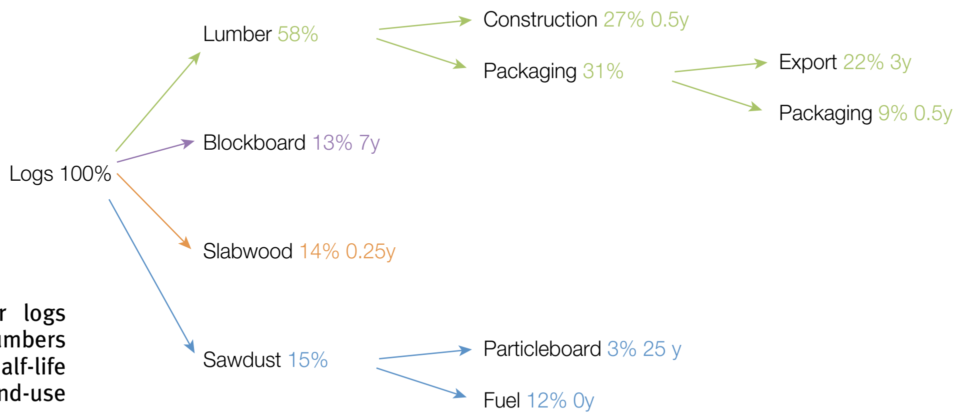

Figure 5: Outline of material flow for logs exported from NZ to India in 2015. Numbers show percentage of volume and pathway half-life (in years) for different processing and end-use pathways

Some mills produce pallets, but most packaging material is supplied directly to packaging plants that are co-located with a major plant that produces pharmaceuticals, glass, auto parts and accessories, turbines/electric motors/generators or electronics. Packaging includes crates and boxes, as well as pallets. Most radiata pine pallets are used for export. Domestic 'junglewood', often Eucalypts, is commonly used for domestic pallets because it is cheaper. Some fruit boxes (e.g. mangoes) are made of pine, as cardboard boxes are easily damaged in the Indian distribution system.

Decay curves for HWP from log exports

The decay curves for the three countries are distinctly different (Figure 6), reflecting the different processing and end-use pathways in each country.

China

Overall the HWP produced in China from New Zealand logs are short-lived with carbon stocks halving in just under two years. Some 46% of the HWP is lumber and plywood used for temporary construction, while 13% is lumber and plywood used for packaging, which is also short-lived. There is a long tail in the carbon decay curve, with 10% of HWP still in use after 23 years. Longer-lived products are the 10% of HWP used for appearance products, including furniture, as well as MDF and particleboard produced from a proportion of sawmill and plymill residues.

The decay curve is most sensitive to:

- The proportion of longer-lived appearance products produced, rather than construction and packaging material
- The percentage of construction material that is recycled into low grade panels, rather than being burnt
- The half-life of the recycled panels
- The percentage of sawmill slabwood and plymill residues that is used for particleboard, rather than pulp.

South Korea

HWP produced from New Zealand logs in South Korea are overall longer-lived than in China, with carbon stocks halving in just over 12 years. Although the 42% of material used for temporary construction has a short-life in that intermediate use, most is recycled into longer-lived particleboard. In addition, 30% of log volume is used for the production of MDF, another long-lived panel product.

The decay curve is most sensitive to:

- The percentage of construction lumber, rather than packaging lumber, that is produced
- The percentage of construction material that is recycled into particleboard, rather than being burnt
- The half-life of MDF and particleboard.

India

HWP produced from New Zealand logs in India are shorter-lived than in China, with carbon stocks halving in less than one year. Some 26% of the radiata pine log volume is directly used for fuel, including slabwood (14%) and most sawdust (12%), while construction lumber (27%) is also used for fuel after use for concrete formwork. Packaging material (31%) is also short-lived, particularly domestic packaging. Only blockboard (13%) and the proportion of sawdust (3%) used in particleboard have a half-life over three years.

The decay curve is most sensitive to:

- The percentage of construction lumber, rather than packaging lumber, that is produced
- The half-life of blockboard.

All countries combined

The decay curve for the three countries, combined by weighting the curve for each country by the relevant log export volume, has carbon stock halving in just over two years (Figure 7). It is no surprise that the combined decay curve is similar to the curve for China, given that this country accounts for 71% of the combined volume, and also because South Korea (18%) and India (11%) offset each other to a certain extent.

The aggregate curve for each country and the combined decay curve are not first-order decay curves, rather it is the weighted average of the first-order decay curves for the different pathways in each country. Although carbon stocks initially halve in just over two years, it takes a further six years for them to halve again, and then 20 years for them to halve for the third time. This is different from a first-order decay curve, where carbon stocks halve repeatedly at a periodicity of the half-life.

The decay curve for HWP from log exports is steeper than that for logs processed in New Zealand (Figure 7), reflecting the shorter-lived products produced from log exports. The implications of this are discussed later. The domestic decay curve is that used by the Ministry for the Environment (MfE) for National Inventory Reporting. It is assumed that there is a 60% conversion from logs to HWP.

Historical trends in carbon stock

By using historical log export volumes, and assuming that the material flow models are applicable to all previous years, it is possible to estimate the

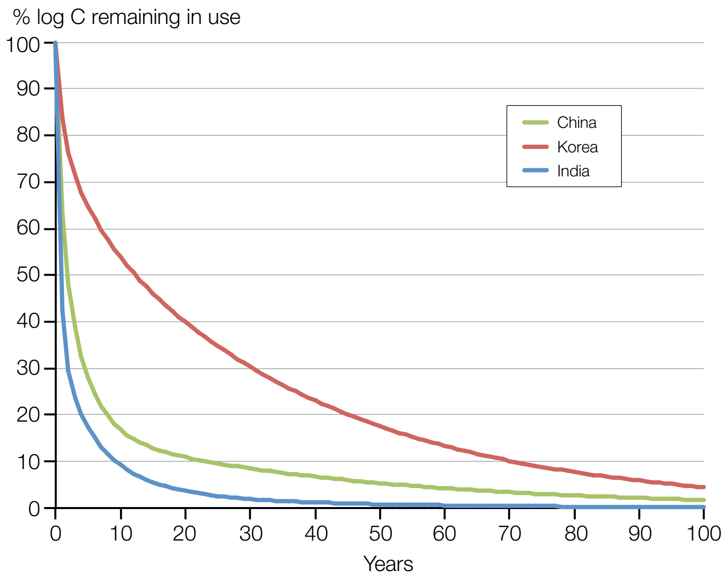

Figure 6: Decay curve for carbon in HWP manufactured from NZ logs exported to China, South Korea and India

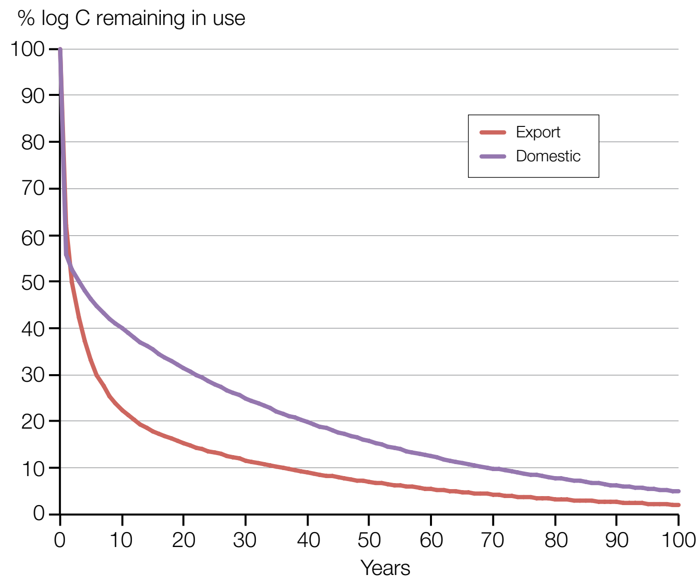

Figure 7: Combined decay curve for carbon in HWP from NZ logs exported to China, South Korea and India. Also shown is the decay rate for logs processed domestically used by NZ in UNFCCC reporting. Source: MfE

development of carbon stock in HWP derived from New Zealand log exports in China, South Korea and India (Figure 8). The relative pattern for each country reflects the volumes exported to that country and the HWP decay rate. Although the HWP carbon stock is currently similar for China and South Korea, the rate of increase is much greater for China. The rapid rate of increase in China has major implications for carbon reporting and carbon accounting because the focus is on the change of carbon stocks over time. However, although carbon reporting under the UNFCCC includes the full-time series, for HWP carbon accounting the pool is initialised in 2013 for pre-1990 forests and 1990 for post-1989 forests.

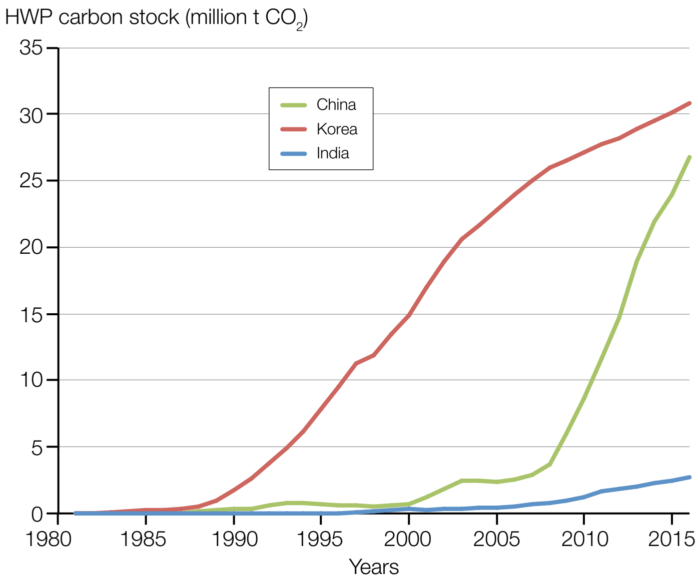

Figure 8: Carbon stock (expressed as million t CO2) development from 1981 to 2016 for HWP from NZ logs exported to China, South Korea and India

Change in carbon stock

Of the three countries, South Korea had the highest rate of increase of carbon stock until 2008. [Japan was the dominant market for New Zealand log exports until 1992. It is not analysed here because current volumes are low (e.g. in 2016, Japan accounted for only 2.5% of New Zealand log exports). The primary end use of New Zealand logs is for packaging – pallets, cable drums, crates.] Since 2008 China has dominated both in terms of the volume of logs imported from New Zealand and the increase in HWP carbon stocks (Figure 9). Confidence intervals since 2010 have typically been ±15% of the mean for China, ±13% of the mean for South Korea and over ±19% of the mean for India.

Carbon stock change is very sensitive to change in export log volumes. For example, between 2013 and 2015, when log exports to China decreased from 11.9 to 10.5 million m³, the annual change in carbon stocks dropped from 4.2 to 2 M t CO_2 per year. Similarly, in Korea when export log volumes reduced from 3.3 million m³ in 1997 to 1.8 million m³ in 1998, carbon stock change went from 1.8 to 0.6 M t CO_2 per year.

Discussion

Implications

There are implications for Kyoto Protocol accounting and UNFCCC reporting. The change in HWP carbon stocks estimated here (Figure 9) will have a material impact on carbon reporting and accounting. In 2013 to 2015, little information was available on the conversion of export logs to products and their expected half-lives. Exported raw materials were therefore excluded from New Zealand's Kyoto Protocol HWP pool estimates, for both pre-1990 and post-1989 forests, and HWP were treated as an instantaneous emission. Future accounting may use the information reported here.

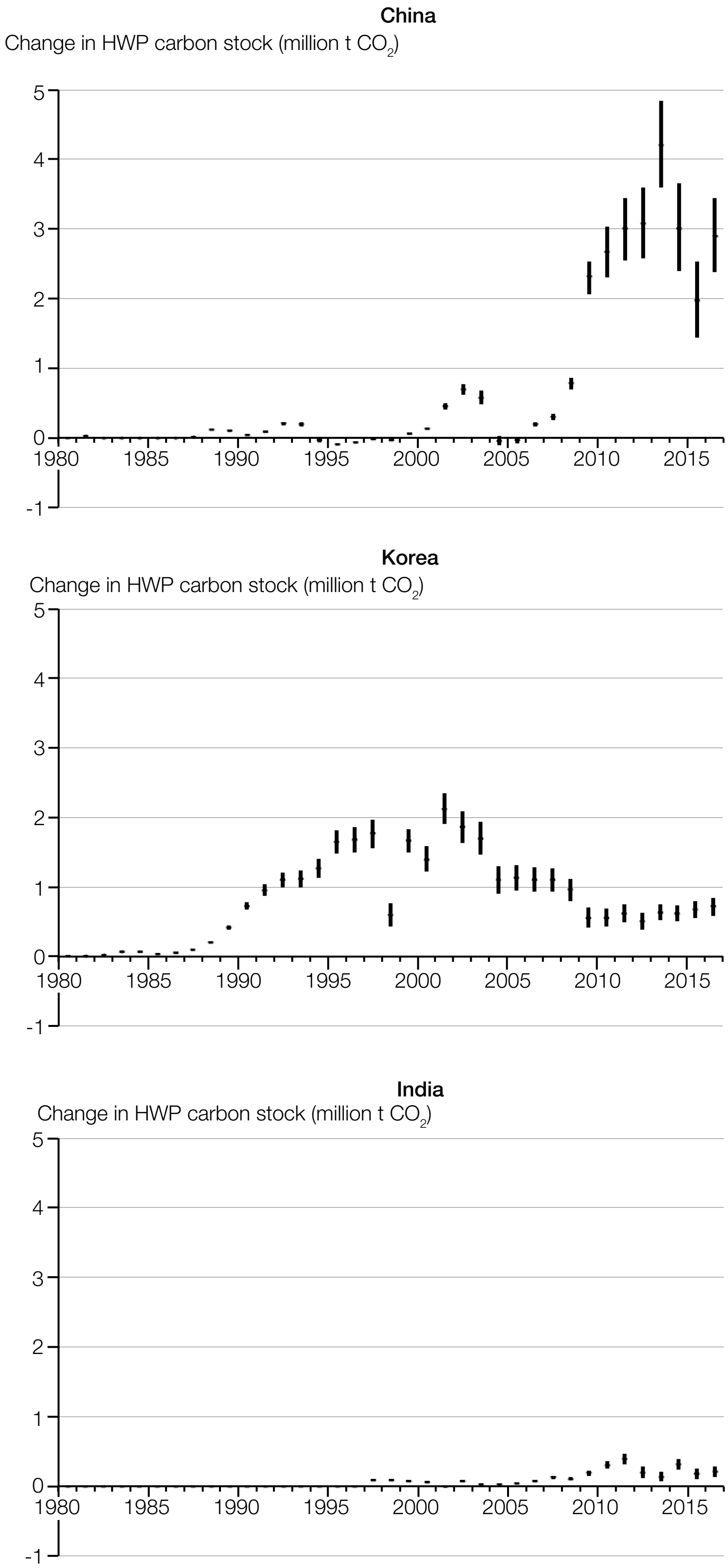

Figure 9: Annual change in carbon stock (expressed as million t CO2) and 95% confidence interval from 1981 to 2016 for HWP from NZ logs exported to: (a) China; (b) South Korea; and (c) India

Estimates of carbon stock increase in 2015 from New Zealand's plantations, excluding HWP, are 1.6 Mt CO_2 for pre-1990 planted forest and 15.7 Mt CO_2 for post-1989 planted forest, some 17.3 Mt CO_2 in total

(MfE, 2017). Estimates for 2013 and 2014 are 17.6 Mt CO_2 and 18.2 Mt CO_2 (MfE, 2017). We estimate that the increase in HWP carbon stocks (HWP associated with any deforestation would be excluded) derived from log exports in these years was, on average, 3.9 Mt CO_2.

New Zealand is reporting HWP under the UNFCCC from the 2013 reporting year in the National Inventory Report (MfE, 2017). Currently, the HWP model used for reporting assumes that exported raw materials are converted into products and consumed at the same rate as domestic production. Although there is no requirement for New Zealand to do so, the country-specific decay curves reported here may be used to increase the accuracy of New Zealand's estimates under UNFCCC reporting. Clearly there will be differences if the specific decay curves for export HWP are implemented in reporting.

There are also implications for the NZ ETS. As part of the NZ ETS review, officials from MPI and MfE are evaluating alternative accounting settings for post-1989 forests within the Scheme. Options being analysed include the inclusion of HWP in post-1989 forestry accounting:

> *With the assumption that New Zealand is to account for HWPs internationally until at least 2030, the Government is considering whether to devolve domestically the deferred liability for emissions from HWPs from post-1989 forests (MfE, 2016).*

As yet there is no preferred position on whether HWP will be implemented into the NZ ETS, let alone the details were it to be implemented. However, one approach being considered is that:

> *Deferred liabilities for emissions from HWPs could be implemented by incorporating emissions from the decay of HWPs and on-site residuals (stumps and roots) into second rotation look-up tables over standard rotation lengths (MfE, 2016).*

The inclusion of HWP has a major impact on the carbon stock profile over time for a tree crop (Figure 10). Using the weighted domestic/export decay rate has a markedly different profile from the current situation where instantaneous oxidation is assumed. With HWP in the current domestic/export proportions, the minimum value of carbon stocks after harvesting the example stand, at age 28 years, increases from 197 to 335 t CO_2/ha and the peaks increase with subsequent rotations for the first five rotations. With only HWP from logs that are domestically processed included, the increase is from 197 to 282 t CO_2/ha. These increases in 'safe' carbon have implications for forest profitability and risk and, consequently, the financial viability of afforestation.

Models are indicative

The material balance models developed are indicative only. They represent an initial attempt to quantify the lifecycle of HWP produced from New Zealand logs exported to China, South Korea and India. Given the scale and diverse nature of these markets, it is a challenge to quantify the end use of these HWP.

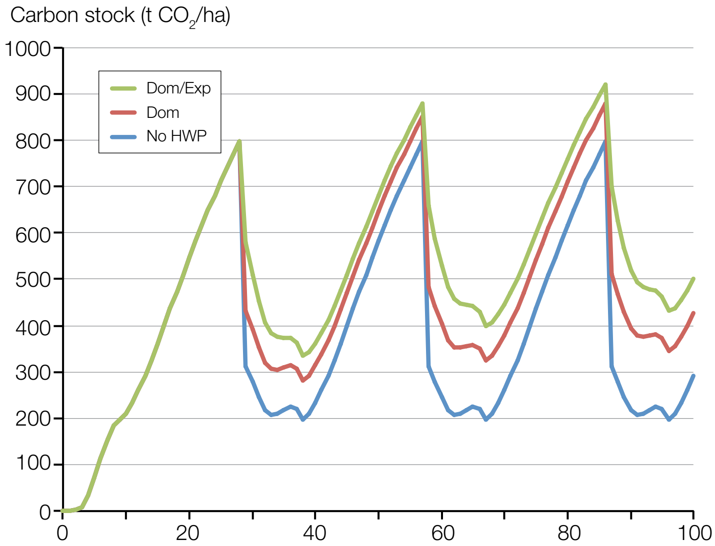

Figure 10: Carbon stocks (expressed at t CO_2/ha) for a radiata pine stand afforested after the ETS is assumed to be changed to include HWP. The stand is assumed to be grown on a 28-year rotation in Hawke's Bay/Southern North Island with: (a) no HWP; (b) only HWP from domestic processing included; and (c) HWP from both domestic processing and log exports. Carbon stocks for the standing crop and residues are from look-up tables (MAF, 2011)

Assumptions

The decay curve estimates are based on 2015 data. To estimate changes in carbon stocks from 1981 to 2016 it has been necessary to assume that the 2015 data is applicable to all other years. The primary end use of New Zealand logs in China, South Korea and India has been for temporary construction in recent years. The proportion of material flowing to each end use depends on the relative economic strength of the drivers of each one.

The demand for timber for formwork depends on the strength of the market for reinforced concrete multi-storey buildings, while the demand for appearance grade timber depends on the domestic and export demand for furniture, mouldings and millwork. Similarly the demand for packaging timber depends on markets, both domestic and export, that require wood packaging and pallets. In addition, the 2015 log exports are mainly from pre-1990 forests. In considering implications for the ETS it has been assumed that the decay curves are relevant to post-1989 forests, including future afforestation.

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